

# Early detection of silent ischaemic heart disease by 24-hour electrocardiographic monitoring of active subjects<sup>1</sup>

Shlomo Stern and Dan Tzivoni

*From the Cardiovascular Laboratory and Cardiac Station for Diagnosis and Follow-up, Hadassah University Hospital and Hebrew University - Hadassah Medical School, Jerusalem, Israel*

*Continuous 24-hour recordings of the electrocardiogram during everyday activities were obtained in 80 subjects with praecordial symptoms, who had normal 12-lead resting electrocardiograms and negative Master two-step tests. The ages of the subjects varied between 41 and 76 years (average 54.7). Forty-three were men and 37 were women, with similar age distribution in each of the sexes. In 37 patients ischaemic ST-T changes were observed during various phases of the day, the incidence being higher among men (55.5%), than women (37.8%). Follow-up examinations 6 to 12 months later in these 37 patients revealed that 1 patient had had a myocardial infarction, 7 others had developed pathological changes in the resting electrocardiogram, and in 16 patients the praecordial symptoms had become worse. In the 43 subjects in whom the 24-hour monitoring was negative, none developed ischaemic attacks, deterioration in clinical symptomatology, or changes in the resting electrocardiogram during the 6 to 12 month follow-up period. We conclude that 24-hour monitoring of the electrocardiogram under normal everyday activity is a reliable and convenient method for detecting ischaemic changes at an early stage.*

The clinical symptoms and physical findings in patients suspected of having ischaemic heart disease are variable, and frequently insufficient for establishing a diagnosis (Short and Stowers, 1972). Pathological changes in the resting electrocardiogram are of paramount importance in making a firm diagnosis of this condition. A normal resting electrocardiogram does not, however, disprove the presence of the disease (Harlan *et al.*, 1967; Master, 1972). Changes in the ST-T segment, the Master two-step test, or other multistage ergometric examinations increase diagnostic accuracy (Bellet and Roman, 1967). In this study we used the method of continuous monitoring of the electrocardiogram during 24 hours for the detection of ST-T changes in 80 patients who had praecordial symptoms, normal resting 12-lead electrocardiogram, and a negative Master test. Six to 12 months later all patients were interviewed again and a resting electrocardiogram performed.

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## Subjects and methods

The continuous 24-hour electrocardiogram was performed on an ambulatory basis through the 'Cardiac Station for Diagnosis and Follow-up' (Stern and Tzivoni, 1973b). During an 18-month period we examined 410 patients with praecordial pain, arrhythmia, or other cardiac symptoms. Eighty of the patients who fulfilled the following criteria comprised the material for this study.

- 1) Praecordial symptoms, typical or atypical of angina pectoris.
- 2) Age above 40 years.
- 3) Normal 12-lead electrocardiogram.
- 4) Negative two-step Master test.

There were 43 men between 41 and 76 years of age (average 54.7) and 41 women between 41 and 75 years (average 54.8).

All patients were equipped with the portable Electrocardiometer Model E<sup>1</sup> of the Holter system. The electrodes were attached to the chest of the examinees as follows: the exploring electrode was placed over the conventional V<sub>5</sub> position, the 'negative' electrode over the right sternal border at the fourth interspace, and the

<sup>1</sup> Avionics, Los Angeles, Calif.

ground electrode over the manubrium sterni. This location produces a complex resembling the conventional V<sub>5</sub> and is the most sensitive for ST-T changes (Blackburn and Katigbak, 1964). In order to exclude orthostatic changes a control electrocardiogram was recorded in each patient in the supine and erect position. During the day of the monitoring the patients were instructed to continue their usual everyday activities and to maintain a meticulous diary, noting all physical efforts, emotional changes, times of meals, bowel movements, excessive changes in temperature, the time of going to sleep, possible dreams or nightmares, and time of rising in the morning. An improved method for interpretation of the magnetic tapes was used (Tzivoni and Stern, 1972). The monitoring was regarded as positive if there was deviation of 1 mm or more for at least 0.1 sec in the ST segment, either downwards with a plane or sagging deformity, or upwards (Lloyd-Thomas, 1961; Simonson, 1970), and/or major inversion of the T wave; this last change, however, if appearing alone is not generally regarded as a fully reliable index of ischaemia (Master, Field, and Donoso, 1957).

Follow-up examinations were done in each patient 6 to 12 months later. The patients were again interviewed for change in symptomatology, hospital admissions, etc., and a resting 12-lead electrocardiogram was obtained.

## Results

### Negative 24-hour recording

Forty-three examinees (19 men and 24 women) did not have any pathological change in the ST segment or in the T wave (Table 1). The average age of the men was 52.8 and that of the women was 53.7. Nine of them gave a history of typical angina pectoris, while 34 had atypical chest pain. The follow-up examination 6 to 12 months later showed improvement in symptomatology in 16 patients, persistent complaints in 24 patients, and worsening in 3 patients. Routine 12-lead electrocardiograms remained normal in all 43 patients (Table 2). None of them was admitted to hospital for a cardiac cause during the follow-up period.

TABLE 1 *Positive and negative 24-hour monitoring in men and women*

	<i>Positive 24-hour monitoring</i>	<i>Negative 24-hour monitoring</i>	<i>Total</i>
Men	24	19	43
Women	13	24	37
Total	37	43	80

### Positive 24-hour recording

Thirty-seven patients (24 men and 13 women) had abnormalities in the ST segment and/or T wave (Table 1). The average age of the men was 56.3 years and of the women 53.4 years. Twenty-one of them gave a history of typical angina pectoris, while 16 had atypical chest pain. The pathological ST-T changes were observed in the 37 patients during normal daily activities, and did not require exceptional effort. Twenty-four of the patients experienced praecordial symptoms during the monitoring period, which were accompanied by pathological ST-T changes; in these patients ST-T changes were detected also during asymptomatic periods. In the other 15 patients no praecordial symptoms occurred during the monitoring period but, in spite of this, ST-T changes were documented. The ST-T changes were more frequent during the hours of activity, and were observed only during physical effort, such as climbing steps (5 patients), during emotional stress, either at work or at home (6 patients), or where effort and emotion were combined (8 patients). In the others, no precipitating factor could be detected for the ST-T changes which in some patients lasted for several minutes and in most of them for periods longer than 30 minutes. In most of the patients (18 cases) changes in both the ST segment and in the T waves

TABLE 2 *Results of follow-up examinations and repeat electrocardiograms in patients with negative and positive 24-hour monitoring*

	<i>Follow-up examinations 6 to 12 months later</i>				
	<i>Symptomatology</i>			<i>Resting electrocardiogram</i>	
	<i>Improvement</i>	<i>No change</i>	<i>Deterioration</i>	<i>No change</i>	<i>Pathological ST-T changes</i>
43 patients with negative 24-hour electrocardiographic monitoring	16	24	3	43	None
37 patients with positive 24-hour electrocardiographic monitoring	13	8	16	30	7

were observed (Fig. 1 and 2). In 9 patients isolated ST depression (Fig. 3), in 4 patients ST elevation (Fig. 4), and in 6 patients major T wave inversion was found (Fig. 5) (Table 3). In all but 3 patients the ST-T changes were observed at a heart rate below 100/min. In these 3 patients the change in the ST-T segment was confined to periods with heart rates of 100 to 140/min.

Follow-up interview 6 to 12 months later revealed no change of symptomatology in 8 patients, improvement in 13, and deterioration in 16. Seven of the patients revealed pathological changes in the resting 12-lead electrocardiogram, 2 were admitted

to hospital because of praecordial pain, without infarction, and 1 of this group developed myocardial infarction.

TABLE 3 Details of ST-T changes in 37 patients during 24-hour monitoring

	No. of patients
ST depression and T wave inversion	18
ST depression	9
ST elevation	4
Major T wave inversion	6

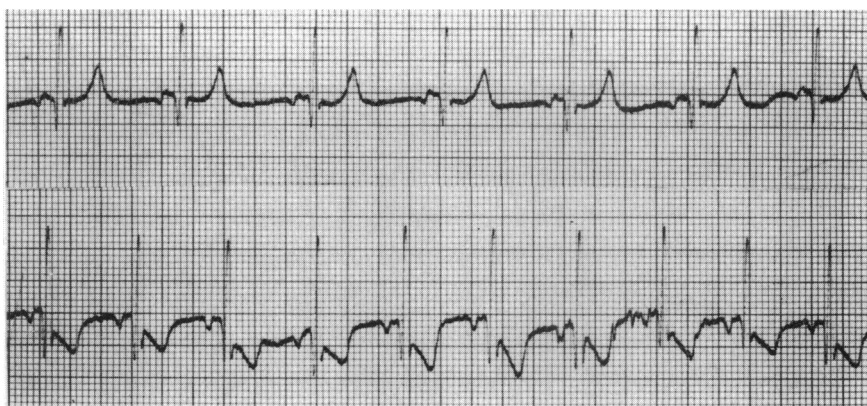


FIG. 1 Representative electrocardiogram during most parts of the monitoring period (top) and during praecordial discomfort lasting 15 minutes (bottom).

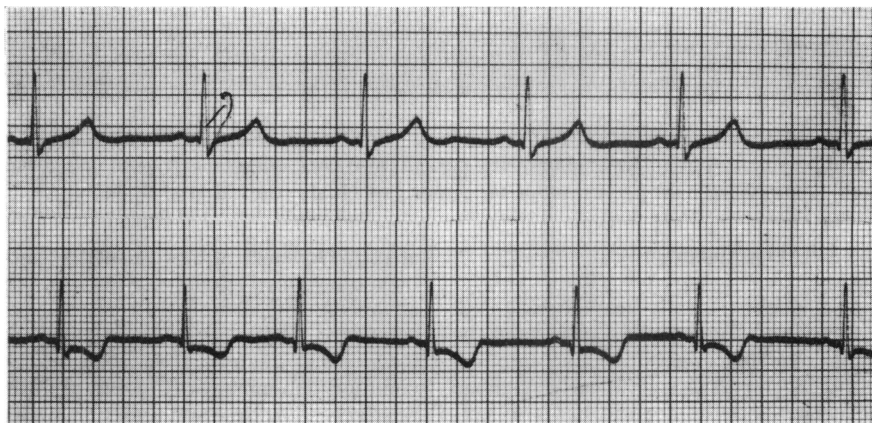


FIG. 2 Representative electrocardiogram recorded during the greater part of the day (top) and ST-T changes occurring without physical effort lasting for 2 hours (bottom).

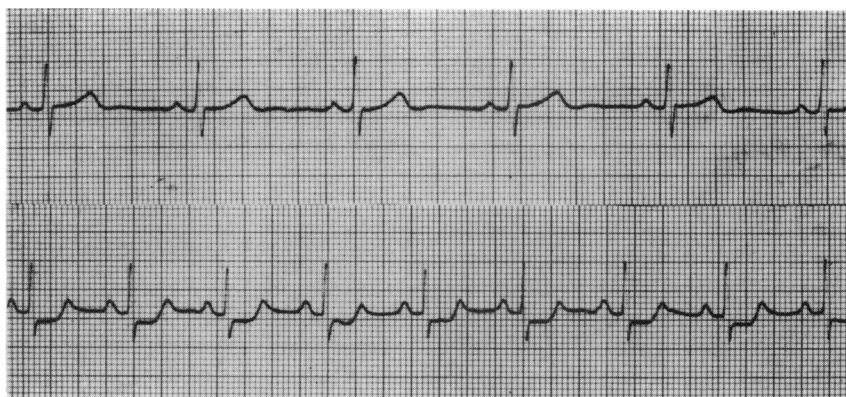


FIG. 3 Representative electrocardiogram at rest (top) and slow walking (bottom).

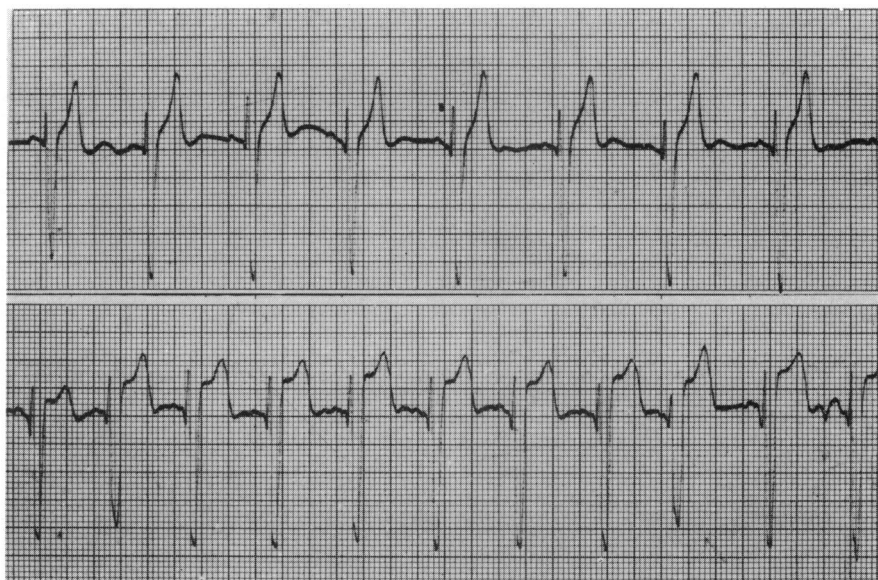


FIG. 4 Representative electrocardiogram in a patient with chronic right bundle-branch block, during most parts of the monitoring period (top) and during chest pain while walking (bottom) (reproduced with permission of the American Heart Journal (1973), 86, 501.).

### Discussion

The early detection of ischaemic heart disease is of utmost importance and has for many years been the subject of numerous investigations. The implications of recognizing the disease at an early stage are not only preventive and therapeutic but also epidemiological, social, and economic. The Master test was the first advance towards diagnosis of the disease in those who had a normal electrocardiogram

at rest. However, the value of this test has recently been questioned (Bellet and Roman, 1967) and more advanced and complicated effort tests have been advocated (Bellet *et al.*, 1967; Sowton *et al.*, 1967; Reynolds *et al.*, 1967). All these methods have the common denominator of being performed during a relatively short time and under hospital or laboratory conditions. The continuous 24-hour recording of the electrocardiogram in active people, reported in this study, provides evidence that dynamic changes

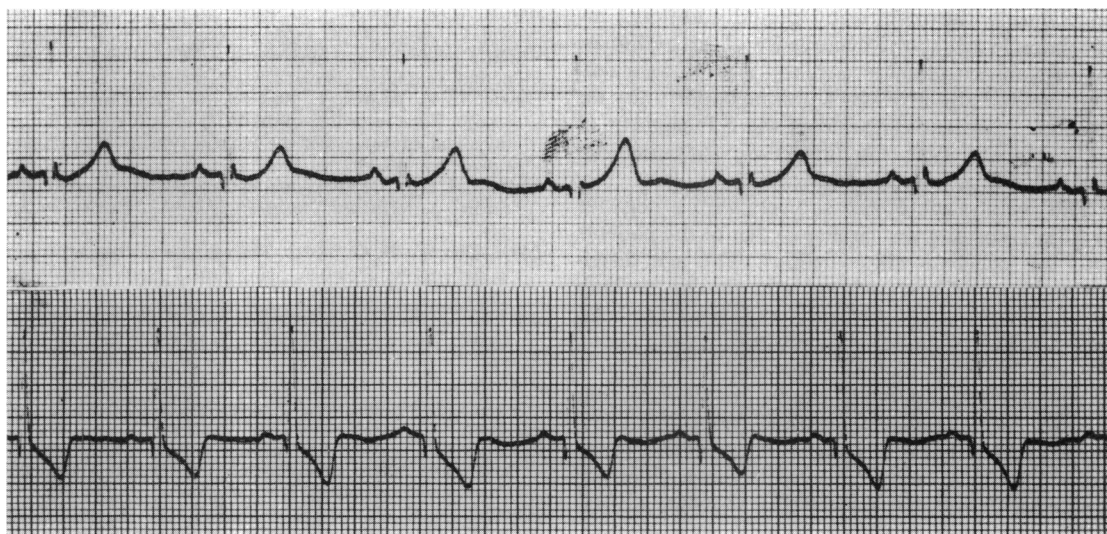


FIG. 5 Representative electrocardiogram during most of the monitoring period (top) and transient major T wave inversion accompanied by precordial pain lasting for 90 minutes (bottom).

in the electrocardiogram do occur under the conditions of physiological efforts and everyday stresses in many patients who have a normal resting electrocardiogram and a negative Master test. In a previous study a good correlation was demonstrated between the ST-T changes revealed by dynamic electrocardiogram monitoring and the results of a multistage bicycle ergometric test (Wolf, Tzivoni, and Stern, 1974).

Earlier investigators used the Holter system mainly for detection of transient arrhythmias (Gilson, Holter, and Glasscock, 1964; Corday *et al.*, 1965; Stern *et al.*, 1970), whereas reports on its use for recording ST-T changes are scanty (Bellet *et al.*, 1968; Silverman and Flamm, 1971; Norland and Semler, 1964). The application of this system for evaluation of ST-T changes was possibly hindered because the accuracy of faithfully reproducing this segment was questioned by Hinkle and co-workers (1967). Recently, the reliability of the more advanced model of the Electrocardiocorder for reproduction of the ST-T segment was proved by comparing the electrocardiograms of patients, with normal and abnormal traces, recorded directly through a conventional electrocardiograph and through the Electrocardiocorder E and its reproduction system (Stern and Tzivoni, 1972). Additional support was supplied by examining the step response curves of the Holter-Avionics system and of a conventional electrocardiograph up to 200 msec,

which is the maximal duration of the ST segment. They were found to be similar (Golding *et al.*, 1973). Moreover, no artificial ST-T segment deviations were seen in 40 subjects below the age of 40 without cardiovascular disease who were examined by continuous 24-hour monitoring (Stern and Tzivoni, 1973a).

In the material presented here, 43 of the 80 examinees revealed no pathological ST-T changes during the 24-hour period. These results correlate well with the follow-up examination of these patients 6 to 12 months later, which showed improvement or disappearance of symptoms in most of them, and no ischaemic event in any of them; repeated electrocardiograms of all these subjects remained normal. In contrast, among the 37 patients in whom ST-T changes were disclosed by the 24-hour monitoring, during the 6 to 12 months' follow-up period, 1 patient developed acute myocardial infarction, in 16 patients the precordial symptoms became worse, and in 7 of them pathological changes appeared in their resting electrocardiogram. Possibly a longer follow-up period will demonstrate the difference between the two groups even more strikingly. The disadvantage of the method of dynamic electrocardiography is the lack of quantitation of the effort performed, but it has the advantage that the examinee is not exposed to exertion to which he is not used, and it lacks the risk involved in exercise tests (Ladimer, 1972). More-

over, during the monitoring period additional information, such as the occurrence of arrhythmias, conduction disturbances, etc. can also be obtained. This method also provides a unique opportunity for detecting transient elevation of the ST segment of the Prinzmetal type (Golding *et al.*, 1973), usually not detected by exercise tests.

The average age of the subjects with a negative 24-hour recording was similar to that of the patients with the ischaemic abnormalities. The age distribution of men and women was similar in both groups. Interestingly, women comprised the majority in the 'negative' group, while in the group with the 'positive' 24-hour recording the men were in the majority. In other words, in the same age group and with similar praecordial symptomatology, women had ischaemic changes less frequently than men. This is in accordance with the well-known higher incidence of arteriosclerotic coronary disease in men.

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Requests for reprints to Dr. S. Stern, Hadassah University Hospital, Jerusalem, Israel.